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(54) IMPROVEMENTS IN OR RELATING TO STRUCTURES WITH PARTIAL DAMPING LAYERS

(71) We, REDUC ACOUSTICS AB, of Fack, Perstorp, Sweden, a Swedish Limited Company, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to a structural element including first and second parts formed of a structural material such as metal, concrete, lightweight concrete, plaster, wood, wood fibres, plastics, or a combination of these materials.

It is previously known to damp a structural element by a so-called sandwich method, i.e., by applying a thin layer of viscoelastic material between two layers of the element. In the Swedish Patent Specification 344,093 (corresponding to US Patent Specification No. 3,828,504) concrete or lightweight concrete structures damped in this way are described, a layer of viscoelastic material which is very thin in relation to the concrete or lightweight concrete layers being applied between the two layers or parts of the structure. In such a structure there is utilized the ability of the viscoelastic material to transform a great part of the vibration energy into heat when subjected to a shearing action on bending of the two structural parts due to vibrations.

Maximum shearing in the damping layer and thereby maximum damping of the structure is obtained when the damping layer is placed in or near the neutral plane of the structural element. When the same material is used on each side of the damping layer this means that the damping layer should be placed so that the total stiffness of a structure damped in this way should be substantially evenly distributed on both sides of the viscoelastic layer.

In known structures the viscoelastic material is evenly distributed in a thin layer over the entire contact surface between the two structural parts.

The most effective viscoelastic materials are characterized by an extremely high loss factor (>1.0), high adhesion—it functions as an adhesive between the structural parts—suitable consistency etc. These viscoelastic materials are expensive.

Adaptation of the viscoelastic material to a structure in order to obtain maximum damping is carried out by suitable selection of the layer thickness and shear modulus (10^5—10^9 N/m², preferably 10^6—10^8 N/m²) of the damping layer. In practice these parameters can be varied only within comparatively narrow limits. For the most effective materials the shearing rigidity of the layer cannot be made low enough and yet retain other desirable properties. Inter alia, the consistency will be unsuitable (the layer material may stick to the work tools) and the adhesion poor.

The application of the damping material is rather time-consuming. When applying it to plates, particle boards, etc., there is a risk of uncontrolled air entrapment.

According to the present invention there is provided a structural element comprising first and second parts of the element separated from each other by a damping layer comprising viscoelastic material, the viscoelastic material extending discontinuously through the damping layer and joining said first and second parts of the element together such that shearing is developed in the viscoelastic material when said first and second parts vibrate in bending modes, the distance between adjacent spaced apart portions of said viscoelastic material being less than the wavelength of a frequency to be damped.

Very good damping results are achieved in accordance with preferred aspects of the invention by using a suitable viscoelastic material having a high loss factor (>0.5) and a comparatively high shearing rigidity compared with corresponding values in viscoelastic material used in prior art structures. Investigations have shown a damping of structures embodying the invention as high as prior art structure with continuous damping layers.

The upper part can be a lattice structure of structual members including supports separated from the lower part by the viscoelastic

material, the stiffness of the lattice structure being preferably of the same rder of magnitude as that of the lower part.

Alternatively, one f said parts, for example, an array of reinforcing members, can be embedded in the other of said parts, said one part being entirely or partially coated with viscoelastic material.

The viscoelastic material of the damping layer can include viscoelastic material in an arrangement of lines, strips, grids or a combination of these, preferably having a material thickness of between about 0.1 mm and 2 mm. It is possible to vary the stiffness continuously over the entire damping layer, i.e. over its total area, for instance by varying the number of portions or their size in order to adapt the damping properties of the structural element to desired values. Tests have shown that it is possible to obtain the same damping with a layer of only 10% of viscoelastic material as compared with 100% coverage, if the aforesaid conditions as to the distance between the covered portions and the adaptation of the shearing rigidity of the damping layer are met.

Because a viscoelastic damping material is active within a limited temperature range, it has hitherto been impossible to achieve a perfect damping within a wider temperature range.

In structures according to the invention it will be possible to widen the temperature range, within which a structure is efficiently damped, by including several viscoelastic materials in one damping layer, each of them having a different temperature coefficient for the shearing modulus.

It has hitherto been difficult to work on damped structural elements of this type, i.e. so-called sandwich elements. In drilling, for example, the viscoelastic material has stuck to the drill, and welding has involved some problems.

In structures according to the invention, there are considerably greater possibilities of working on a sandwich element, as the positions of the portions of viscoelastic material can be marked on the upper face of the element and the work can be carried out as far as practicable within the areas not covered by damping material.

The application of viscoelastic material in accordance with the invention can be simply carried out, whether in the form of lines, spots or a grid arrangement, by automatic application devices, and the right layer thickness can be obtained by pressing or rolling an upper part against a lower one. Hence it follows that the working effort in forming a structural element in accordance with the invention is considably less than in applying the material using conventional techniques.

Because part of the element of homogeneous structural material can, according to an embodiment of the invention, be replaced by a framework or similar lattice structure having the same stiffness, sufficient stiffness can be achieved with comparatively small material consumption and, thus, low structure weight.

When casting a damped concrete structure with a damping layer to form a structural element according to the invention it is possible, in order to avoid the two parts being cast together at places not covered by viscoelastic material, to place on the lower part a covering sheet, for example, of sheathing paper or plastics foil with apertures for the insertion of the viscoelastic material. Alternatively, the viscoelastic material can be applied to one or both sides of a carrier (e.g. sheathing paper).

The invention is further described by way of example with reference to the accompanying drawings, wherein Figure 1 shows a section of a conventionally damped structure, Figure 2 shows a section of a damped structure according to the invention, Figures 3 and 4 show two sections perpendicular to each other through a structure embodying the invention wherein the upper part is in the form of a framework structure, Figures 5 and 6 show sections perpendicular to each other through a further concrete structure embodying the invention, Figure 7 shows, as seen from above, a part of a concrete structure in production, and Figure 8 shows a section along the line VIII—VIII of Figure 7.

In Figure 1 a conventionally damped structure is shown, consisting of two superimposed parts 1, 2, e.g., two metal plates, concrete slabs, plaster sheets, wooden fibre sheets, between which a thin continuous damping layer 3 of viscoelastic material is applied,

A damped structure according to an embodiment of the invention (Figure 2) comprises the same parts, i.e. plates, etc., 1 and 2, but has spaced portions of viscolelastic material in the damping layer, which may consist of distributed lines or spots 4 of viscoelastic material. The distance a between these lines or spots 4 is less than one wavelength of the highest frequency against which the structure is to be efficiently damped, preferably rather less than a third of such a wavelength.

In Figures 3 and 4 there is shown how according to another embodiment of the invention, the upper part of a layered structure can be in the form of a lattice or framework 5 of, e.g. wood, which is arranged upon a concrete slab 6. A damping layer in the form of spots or patches 7 of viscoelastic material is arranged between the supports of the framework and the concrete slab.

In Figures 5 and 6 there is shown how, according to a further development of the invention in a monolithic structure, near the surface of one part 9 there is embedded the other part in the form of an array of rein-

forcing members, herein shown as box-like girders 8, a layer of viscoelastic damping material 10 being applied to the members to allow for relative shear.

When producing a damped concrete structure embodying to the invention, a sheet of sheathing paper 11 (Figure 7) can be used, which is placed onto the first cast part or slab 12, whereupon apertures suitably distributed in the sheet are filled with viscoelastic damping material 13 (Figure 8). Thereafter, the upper part or slab, not shown here, can be cast.

WHAT WE CLAIM IS:—

1. A structural element comprising first and second parts of the element separated from each other by a damping layer comprising viscoelastic material, the viscoelastic material extending discontinuously through the damping layer and joining said first and second parts of the element together, such that shearing is developed in the viscoelastic material when said first and second parts vibrate in bending modes, the distance between adjacent spaced apart portions of said viscoelastic material being less than the wavelength of a frequency to be damped.

2. A structural element according to Claim 1 in which the viscoelastic material of the damping layer is in an arrangement of lines or patches or is in a grid arrangement.

3. A structural element according to Claim 1, in which one of said parts is of homogeneous structural material and the other of said parts is a lattice structure of structural members including supports separated from said one part by said viscoelastic material.

4. A structure according to Claim 1, in which one of said parts is embedded in the other of said parts, said one part being entirely or partially coated with viscoelastic material.

5. A structural element substantially as hereinbefore described with reference to Figure 2, or to Figures 3 and 4, or to Figures 5 and 6, of the accompanying drawings.

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FIG.1

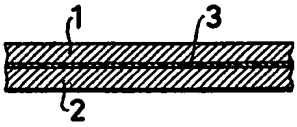

FIG.2

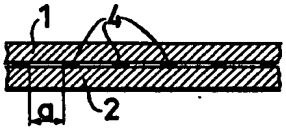

FIG.3

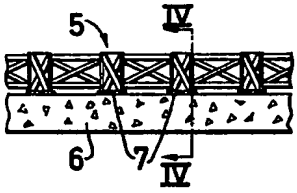

FIG.4

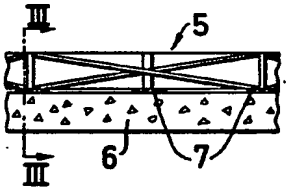

FIG.5

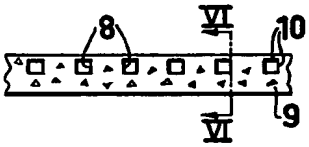

FIG.6

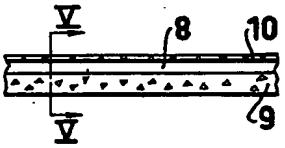

FIG.7

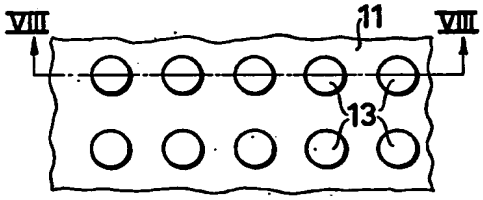

FIG.8